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EVIDENCES OF ATTACKS BY THE WESTERN PINE BEETLE AND MOUNTAIN PINE BEETLE IN THE PACIFIC SLOPE FORESTS.

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Foreword.

A growing realization of the importance of forest entomology in the protection of both public and private forests has brought with it the need for standard methods of recognizing and estimating insect losses. The problems developed by insect depredations in forests of merchantable timber must be expressed in terms of forest values before their importance can be demonstrated. A record of the mere presence of tree killing insects does not furnish the basis upon which to formulate a policy of forest protection. It is essential to know the extent to which insects are depleting the stand, the possibility of an increase or decrease in their attacks, and the bearing of other factors which must be expressed quantitatively.

Any methods that are used in forest insect surveys must be practical enough to be readily appreciated and used by an experienced timberman. It is essential that the cruiser be qualified to recognize and distinguish the trees which have been killed by insects, but a specialized knowledge of entomology,

although desirable, is by no means a requisite in estimating insect losses. In the field work emphasis should be placed upon the accuracy and adaptability of the data as it applies to timber losses. Technical matters relating to entomology belong to a distinct field of investigations and to give them an unnecessary amount of consideration may result in the sacrifice of time needed for practical phases of reconnaissance work.

As a result of his studies during the period from 1890 to 1900, Dr. A. D. Hopkins, then of the West Virginia Experiment Station, was able to arrive at comprehensive estimates of the loss caused by insects in North America forests. The earlier publications of this author first brought to public notice the importance of forest insect problems and emphasized the fact that forest entomology should be considered in any effective system of forest protection. This work has served as a basis for our present methods of recognizing and estimating insect losses. The present publication covers the work which has been carried on during the past eight years under his instructions and deals with the evidences by which forest insect losses can be recognized in the pine stands of the Pacific Slope region. The field is limited to the two most important Dendrcotonus which have been found to be primarily responsible for the greater part of the loss in pine stands.

FOREST INSECT SURVEYS.

Purposes.

The purposes of systematic forest insect surveys may differ. Usually they are carried out with any one or several of the following objects in view.

1. To obtain information on the cause of the dead timber, determine the primary infesting insects and locate their general distribution. The attention is confined more to entomological features, and systematic estimates of the volume of loss are considered secondarily.

2. To obtain estimates of the volume of timber which is being killed by one or more species of insects within a definite forest area. The emphasis in this work is placed upon accurate quantitative data and considerable attention must be given to standard methods of estimating timber volumes. This data is essential as a basis for determining the importance of the insect problems and the necessity for undertaking control measures.

3. To locate and mark the infested trees for forest insect control projects. This survey, which is usually carried out just preceding the treatment of the infested trees, is for the purpose of detecting the trees which contain broods of insects, determining such trees as should be treated, and locating them by maps so that they can be found by control crews.

Methods of Field work.

Forest insect surveys, to be practical, must employ methods of field work which will yield results of sufficient accuracy to warrant their application in forest management; furthermore, the cost of the field work should be in keeping with the value of the data collected.

The amount of infested timber is not a fixed quantity like the total volume of the stand. Insect depredations fluctuate from year to year and a survey ~~of the loss for~~ estimate of the amount of timber killed during any one year will not apply to any other year. The most accurate data which can be secured is only of transient value and it is evident that surveys of insect loss must be frequently repeated if the essential information is kept up to date.

In forest insect surveys the estimator is concerned primarily with only a limited per cent of the stand. His first purpose is to recognize and to segregate the insect killed timber from the other classes of trees within the forest. Granted his ability to do this, the methods by which he determines the volume of the loss may be any of the standard methods of forest mensuration and computation. Methods of estimating and computing the volumes of insect killed timber do not differ in any important respect from the methods used in the estimates of the standing green timber.

A project of estimating the insect loss on an area is usually undertaken by one or the other, or a combination of both, of the following methods which differ only in the intensity with which the territory is covered.

1. Extensive Reconnaissance on Topographic Viewing.

Where topography permits, the estimator covers the area by traveling along the more important ridges, and from prominent points counts the visible insect killed trees which can be seen within a distance of not more than two miles. These trees are distinguished by their affected foliage, which is of a characteristic fading or reddish brown color. If it is impracticable to view the area to advantage because of level topography, or factors which interfere with good visibility, the tract is traversed by regular strips, or by roads and trails, and all trees that can be seen within a short distance of the line of traverse are counted. Trees thus counted are located on a base map, and all trees that can be conveniently reached are examined to determine the cause of death and to measure their diameters. The trees which are located and examined represent only a portion of the total insect-killed trees on the area. It is evident that a considerable number of the recently killed trees will not be discovered by the cruiser, no matter how careful he may be, because of their being hidden by surrounding green trees, or because they are cut off from the range of view by topographic depressions and ridges. To the number of trees which he is able to see and count a factor must then be applied to arrive at the total of infested and insect killed trees existing on the area. This factor is worked out by making an intensive cruise of sample plots. Extensive methods are nearly always used where large forest areas are involved and where the purpose is that of a preliminary survey to determine the advisability of control work.

2. Intensive Surveys or Cruising.

Under this method an effort is made to locate, mark and examine every recently killed or infested tree on the area under consideration. To do this it is necessary to work the area so that each individual tree, whether green or insect-killed, is brought under observation within a comparatively short distance. This involves running compass strips across the area as close as four strips through a forty, or working the area by topographic divisions so that the ground is carefully and consistently covered. By this method it is possible to locate, so far as they can be detected, all of the insect killed trees on the area. The infested and insect abandoned trees which are located are examined at the base and marked or numbered. Necessarily, this method is slow and consequently expensive and is used for sample plots or for tracts of timber under special study. Intensive methods are always used in marking infested trees preliminary to control work.

As a rule a systematic forest insect survey is carried out by using a combination of both the extensive and intensive methods, the intensive surveys being used on sample plots to supplement the extensive reconnaissance of large areas.

Foliage of Trees of Primary Importance.

These methods of determining the amount and character of insect damage are briefly outlined here to indicate the vitally important part that the foliage color of infested or abandoned trees plays in any method of forest insect surveys.

The forests of the Pacific Slope and Rocky Mountain regions embrace such vast areas of virgin stands that methods of insect surveys which involve the basal

examinations of every tree must necessarily be restricted in their application. It is evident that for the present at least our examinations of these forests must be carried on by methods which will permit of the examination of large areas within a comparatively short time. For this reason the greater part of our estimates of loss must be based upon trees which are seen and estimated from a distance.

In all extensive work the cruiser first recognised that a tree is affected by the significant change in the color cast of the foliage. Whether the estimator's purpose is to locate and mark the number of infested trees,, or to determine the amount of annual loss within the stand, he is guided first of all by the changes in the foliage color of infested and abandoned trees. Other characters are indispensible in ~~locating~~ detecting and marking infested trees, such as pitch-tubes ,saw-dust borings, characters of insect work under the bark, but the color of infested trees may be said to play as important a part in the location of insect infestations as that of smoke in the location of incipient fires.

Evidences of Insect Infested and Dead Abandoned Trees.

Following a successful attack by Dendroctonus beetles or associated species upon the bole of a coniferous tree, the foliage color changes from normal to a noticeably paler green. This is followed by a yellowish tinge which soon ~~partially~~ turns to a red or reddish brown color. This transformation from green to red

occurs within one season after attack. After one or two winters these red needles blacken and fall, leaving only the black limbs and twigs. When trees reach this final stage, which is known as the "black top", the color condition is quite inconspicuous and it is often a very difficult matter to distinguish such trees in distant viewing. As a basis for his estimates, the cruiser must depend almost entirely upon his ability to distinguish and count trees after the first fading appears and before the black top stage is reached.

In certain types of infestation, such as the western pine beetle in yellow pine in the Pacific Slope Region, foliage is a much more important and reliable criterion than in others. In mountain pine beetle infestation in lodgepole pine and yellow pine, the foliage fades so slowly that it sometimes fails to be a useful factor in locating freshly infested trees. But in any system of extensive reconnaissance the evidence supplied by the foliage must always remain the first index to the infested condition of a forest and the estimator who fails to properly interpret foliage evidences ~~can never estimate~~ is at a great disadvantage in estimating successfully insect loss or marking infested trees.

Definitions of Terms Describing Color Phases.

Certain terms are essential in describing the color phases and of infested trees and a set of standard terms have been defined.* It is essential to adhere

*Hopkins, A. D. Bull. 83, Part I, Bureau of Entomology, 1909.

to established basis terms, although there are variations to all the color phases of trees and the various stages of color may so merge that they are difficult to distinguish. It is also essential that as few terms as will possibly meet the requirements of practical work should be adopted in order to avoid confusion in the interpretation of color phases. The following definitions in quotations are those given by Dr. A. D. Hopkins.

Fading tops.- "The fading or noticeably paler green of the foliage of infested trees."

This is the first indication of the foliage by which it is possible to distinguish an infested tree. In its first stages it applies to a sickly appearance of the needles, although there is no appreciable change in color. Fading foliage is a very transient condition and changes rapidly to the more advanced color phases.

Sorrel tops. - "The yellowish foliage of trees dying from the attacks of beetles."

Sorrel foliage appears within a month or two after the trees fade. Several phases of colored foliage are classed as sorrel top, varying from a greenish white to a yellow with distinct reddish tinge. Sorrel tops may last for several months before they turn red.

Red tops. "The color of the foliage after the tree is dead and usually after the broods of destructive beetles have emerged from the bark."

This is a distinct phase of color appearing from two to six months after the foliage fades. Red top trees are not as conspicuous as sorrel tops because of

the much darker color of the foliage. Needles of red top trees gradually darken, changing from a bright red to a dark red color after the first winter. The red top stage lasts until the red needles have fallen and the black top stage begins. The red top stage usually persists through the second winter after the tree fades, although many trees lose the majority of their red needles after the first winter.

Black tops.- "The condition of the dead trees after all of the leaves have fallen and two or more years after the beetles have left them."

This condition is reached gradually. The needles usually fall first from the upper part of the tree. A tree may have a black top, although there are still a few red needles adhering to the lower limbs. After trees reach the black top stage their color is no longer conspicuous and it is often difficult to distinguish them in distant viewing. Many trees turn black following the first severe winter and practically all trees reach the black top stage following the second winter after attack. This stage lasts until the bark begins to fall from the trunks and limbs. The extent of this period is indeterminate but it usually lasts from six to eight years.

Ghost trees. This term as applied to the Pacific Slope region has been proposed to describe the final stage of the standing insect killed trees which appears after the bark has fallen from the trunks and limbs and the white sapwood of the trunk makes them conspicuous. Six or eight years may be required to reach this condition. Many insect-killed trees do not reach the ghost tree stage, as decay, borers, or windstorms cause them to fall within a few years after they are killed. Ghost trees are in evidence in dry rather than in moist climate.

Application of Color Phases in Surveys.

The estimator is obliged to depend almost entirely upon the first three color phases of the foliage (fading, sorrel and red) as the basis of his counts of

infested and abandoned trees. Black top trees are very difficult to see, even from a short distance, so that it is possible to distinguish but a very limited number of trees of this class in extensive surveys. Beside the difficulty of distinguishing black top trees, the period of loss which they represent is too indefinite and remote to be of great value in the interpretation of existing conditions. Both the black tops and ghost trees, however, may serve to indicate the character and extent of preceding losses.

Trees which are counted by the extensive method of viewing an area are those with sorrel and red foliage. Fading, sorrel and red trees can be distinguished from healthy trees in the forest at a considerable distance and they represent an approximately definite period of recent loss. Continued field observations during the past six years indicate that the insect infested and abandoned trees in this foliage condition represent a period of loss covering approximately two years.

In intensive surveys and sample plots, all classes of infested and dead abandoned trees may be considered, according to the purpose or methods of the survey. The difficulty of distinguishing black top trees is largely removed in intensive work, as the distance at which all trees are viewed does not exceed two or three hundred yards.

The transition from one color stage to another and the ease with which the different stages can be distinguished varies greatly in individual trees. This may be due to the habits of the primary species of infesting barkbeetles, the species of conifers attacked, and the season of the year when the attack is made. Fading foliage follows the attack of the western pine beetle much more quickly than it does that of the mountain pine beetle. Trees attacked by either species during the heat of the summer fade more quickly than those attacked late in the fall which often do not fade until the following winter season is over.

Much of the variation in foliage conditions, however, is due to individual variation in trees, just as the normal green foliage may be lighter or darker in individual trees of the same species. An allowance must also be made for the varying color preceptive of individual estimators which is sometimes responsible for different interpretations of the foliage color of the same tree.

Evidences of Attack upon the Bole.

While foliage is the first indication upon which the estimator relies for distinguishing the insect-killed trees from the normal green stand, it is essential to take into consideration other evidences in the determination of the insects which kill the trees. Many of the fading or red trees may not be killed by insects at all but by other causes. The base or upper part of the trunk must be examined

for pitch-tubes, sawdust borings, egg galleries or larvae, which are the only positive evidences that the tree has been attacked by barkbeetles. For this reason, under any method of reconnaissance, a basal examination must be made of at least a part of the trees which have been counted as insect killed because of their colored foliage.

Rather than depend upon either of these external evidences of barkbeetle attacks, an examination of the cambium should always be made. This is done by removing the outer bark so that the sapwood or inner bark is exposed. The egg galleries and larval mines of the attacking barkbeetles are thus exposed and furnish conclusive evidence of the species involved. Each species of barkbeetles has characteristic habits of excavating and extending its egg galleries and these, together with the larval mines, are an available and very reliable means of determining the primary species of beetles. For field work these evidences of their work are a much more satisfactory means of determining the insects than an examination of the actual specimens of adult barkbeetles.

A close examination by the cruiser is limited to that part of the trunk which he can reach from the ground. The first evidence looked for in this basal examination is that of pitch-tubes upon the outer surface of the bark. These small resinous masses are often conspicuous, but they are by no means a regular

occurence in all trees attacked. In the case of the western pine beetle, pitch-tubes are few and inconspicuous and are seldom noticeable in more than 50% of the trees. Another indication of attack is the presence of saw-dust borings in crevices of the bark or at the base of the tree. These saw-dust borings are not always plentiful enough to be easily seen, although they invariably result from extension of egg galleries by the parent beetles.

Foliage Affected by Causes other than Insects

Other factors to be considered besides insects which cause fading of the foliage are pathological diseases. The color phases of trees so affected are at times almost identical with those resulting from insect attacks. Areas have been sometimes encountered where both insects and diseases prevail and the problem of distinguishing between the two in extensive surveys is a very difficult one.

Fire scorching is another cause of a foliage condition resembling that found on insect-killed trees. As a rule, however, fire scorched trees do not pass through the fading and sorrel stages, but take on a deep red color soon after the fire. The color cast of fire scorched trees differs somewhat from those which have been killed by insects, and with experience they can sometimes be distinguished even at a distance. Upon close examination the evidences of fire are of course unmistakable. Very often, however, barkbeetles attack fire scorched trees, resulting

in a complication of insect and fire damage which can only be worked out by the estimator.

On any extensive forest area a few trees are frequently seen which show the characteristic fading sorrel and red color phases, but which, upon close examination, do not appear to have been attacked by insects, disease or fires. Such trees may be affected by some organic disturbance, the diagnosis of which requires a specialized knowledge. In forest insect surveys the cause of death of such trees can only be classed as unknown. Trees dying from unknown causes often amount to a small but appreciable per cent of the annual loss.

Top-killed Trees.

During some seasons the cruiser will encounter a number of trees in which only the upper part of the foliage has been affected, while that on the lower limbs is green, but the bark and cambium at the base are in a healthy normal condition. In other trees the affected condition may include the foliage of the entire tree, while the cambium at the base fails to show any evidence of insect or disease. Such trees may or may not contain considerable insect infestation above the green base. Barkbeetles frequently attack only the upper twenty feet or so of the tree, or they may extend their attack down the bole to within ten or fifteen feet of the ground, but still there is no evidence at the base to indicate the character of the

attack on the upper part of the tree. Top-killing of trees may also be due to disease or unknown causes. Experience gained in actual field work will usually lead an estimator to recognize the probable cause of top-killing on the area he has under consideration, but the examination of a number of these questionable trees, either by felling or climbing, is necessary as a basis for interpretation.

Primary Importance of the Western Pine Beetle and Mountain Pine Beetle.

All surveys which have been conducted to date emphasize the predominance of the western pine beetle and the mountain pine beetle over all other organic causes in the killing of pine timber in the Pacific Slope region. A careful study of the annual loss in Rogue River and Klamath River watersheds in Southern Oregon and Northern California brought out the fact that the western pine beetle in yellow pine alone was responsible for 90% or more of the total annual loss during the four seasons from 1914 to 1917 inclusive. The mountain pine beetle in sugar pine ranked second, the loss amounting to about 8% of the total. Other causes contributed to about 2% of the total.

An extensive survey of the pine belt in the southern part of the Sierra Nevada mountains of California in 1917 indicated a total seasonal loss of 29 million board feet. The western pine beetle in yellow pine contributed to about 60%; the

mountain pine beetle in sugar pine about 40% of this total. Other species involved in the loss were of but little significance except the Jeffrey pine beetle which attacks only Jeffrey pine.

In any survey within this region, therefore, the ability to recognize the attacks of these two primary species of barkbeetles is essential.

Relation of Seasonal History to Annual Loss.

Both the western pine beetle and the mountain pine beetle may develop more than one generation annually. The new adult beetles which emerge in the spring or early summer from trees in which the broods overwintered soon make their attack and deposit their eggs in new trees. If climatic conditions are favorable, the broods hatching from these eggs will develop to new beetles and emerge from the tree before the close of the summer, thereby constituting the first complete seasonal generation. The new beetles which emerge may then attack and deposit eggs in another tree, starting the second seasonal generation, which may or may not complete its development before the winter period sets in. Bulletin 83 from studies made in Idaho indicates that the seasonal history of the western pine beetle reaches a development of one complete seasonal generation and a partial second. Further Studies by this Bureau continued since that date indicate that this is a very fair average for the entire Pacific Slope region. Where the climate permits there may be a

maximum of two complete seasonal generations and a partial third, while in cold situations the maximum probably does not exceed one complete seasonal generation. The mountain pine beetle is limited to the development of but one generation annually, except in the lower elevation of the southern Sierra region where it apparently develops a partial second seasonal generation.

However, individuals of the same brood do not develop uniformly. Some individuals develop rapdily and emerge promptly; others retard their development and emergence for an indefinite period. It is apparent that individual trees are seldom attacked uniformly by the representatives of any one seasonal generation and that the same tree may be attacked by the representatives of several true generations of beetles. Everywhere there is a complex overlapping of generations and the distinguishing of individual trees according to their seasonal generations is one of the most difficult of all problems in field work.

As the total annual loss for any one calendar year consists of all trees successfully attacked during the season of activity of that year, the estimates must include trees of all the seasonal generations represented by this attack. But, as has already been shown, it is practically out of the question for the cruiser to distinguish true seasonal generations in field work. If an examination is made of a tract of timber at the close of the active season, as in November, the cruiser will find that the trees attacked during the current season can be separated as follows;

1. Trees which were attacked during the spring or early summer and in which the broods have completed their development and emerged before fall. These may be designated as the summer brood trees. In localities where the season is short trees representing the summer brood may be entirely lacking.

2. Trees which were attacked during the summer or fall in which broods do not complete development until the following year. In these trees the insects pass through the overwintering period and emerge the following spring or summer. Such trees are known as the overwintering brood trees.

The total volume represented by trees of the summer brood and the overwintering brood constitutes the annual or seasonal loss for the year. The trees of these two classes can be fairly easily distinguished at any period when the marking is made, ~~either for the current year~~ if they have been attacked during the year of the examination or the one just preceding.

If the infested trees only are counted these will represent a per cent of the total annual loss, depending upon the length of the active season and the proportion of the broods which complete their development before winter. Some individual trees will be found in which part of the broods emerge in the fall, while the remainder retard and overwinter before emerging. Such trees may be classed either as summer brood or overwintering trees, according to the proportion of the broods which overwinter. In any case, however, they fall within the seasonal loss of the year in which they are attacked.

Evidences of Attack by the Western Pine Beetle.

This species confines its attacks to but one host tree,- yellow pine. In this respect it differs greatly from the mountain pine beetle which attacks a wide range of coniferous hosts. Its distribution extends throughout the Pacific Slope region from Southern California northward and through the Northern Rocky mountain region wherever yellow pine occurs.

Foliage:

Trees attacked by the western pine beetle fade rapidly after an attack during the growing season. This is due to the form of the egg galleries which cut diagonally across the inner bark, completely gridling the tree, if the attack is successful. The change from fading to sorrel and later to red progresses rapidly and the foliage becomes red within a few months. Trees which are attacked late in the fall, however, may not fade until the following spring and the development of all color phases is checked during the winter months.

A very careful study of the color phases of trees attacked by the western pine beetle was made by Mr. F.P.Keen at Ashland, Oregon during the period from 1915 to 1917. His results show that there is considerable difference in the advance of the color phases between trees of the summer brood and those of the overwintering brood. Following the attacks which occur during the spring and

early summer in yellow pine the trees fade rapidly, frequently within tro or three weeks. The fading of all of the summer brood trees is completed before autumn. Usually the period of fading of the summer brood trees extends from May 15th to September 1st. Trees attacked during the late summer and autumn which contain the overwintering broods are inclined to fade much more slowly than those containing the summer broods. A varying percentage of the trees of the overwintering broods fade before the winter period sets in. Many of them, however, remain green during the winter and do not fade until warmer weather occurs and development sets in the following spring. Some few overwintered trees may not fade until the summer period begins.

The stage of development of the broods at the time when trees turn from green to fading varies greatly in individual trees. There is no apparent reason or explanation for the extreme variation which occurs in some trees. Some fade almost immediately after attack. In others the trees may remain green almost up to the time that the emergence of the new broods is complete. Such cases occur but rarely.

There are variations to the color gradations in all three of the dominant phases of fading, sorrel and red foliage. Trees which fade quickly during the hot summer months often turn from the first fading appearance to a light straw-colored

or silvery yellow color which has led to the use of the term, "White top" in field work. So far as brood development and other conditions are concerned this is only a phase of the sorrel top stage and is without special significance, except that such trees are very conspicuous and almost always infested. The light color soon changes to deep sorrel before changing to red. The first phase of the red stage is a rather bright red cast which gradually advances to dull red or a reddish brown.

Mr. Keen's studies of D. brevicomis trees show that as a rule the trees fade after the larvae hatch and at about the time when they enter the outer bark. Normally, trees turn sorrel at about the time of maximum pupation and before the forming of the new adults and change to the red stage about the time of the maximum emergence of the beetles. The majority of the trees in the red foliage stage are abandoned.

Evidence of Attack at Base.

In trees attacked by the western pine beetle pitch-tubes of sufficient size to be conspicuous occur only occasionally and cannot be relied upon as an evidence of attack. Sawdust borings are also scant and seldom plentiful enough to be conspicuous. The only satisfactory means of identifying the infestation of this species is to remove the bark so that the characteristic egg galleries of the beetles

can be seen. If the brood has not advanced beyond the egg or first larval stage it is necessary to cut into the inner bark or sapwood to find this evidence. To locate the advanced stages of the broods it is necessary only to chip off the outer scales of the bark, cutting just deep enough to uncover larvae, pupae and new adults.

The only reliable evidence of infestation, aside from a basal examination of the bark, is that of woodpecker work. Woodpeckers in feeding upon the western pine beetle look for advanced stages of the broods and chip off only the outer scales of bark. This habit gives a characteristic appearance to the bark, quite different from that produced by bird work on the mountain pine beetle.

Evidences of Attack by the Mountain Pine Beetle.

Unlike the western pine beetle this species attacks a variety of hosts, such as western yellow pine, sugar pine, lodgepole pine and western white pine. It is recognized, however, by the same foliage conditions and characteristic work in all hosts.

Foliage.

As a rule trees fade rather slowly after an attack by this species. The egg galleries which are extended by the parent adult beetles in entering the tree do not completely girdle it, as they advance more or less vertically up the trunk

following the grain of the sapwood. The larvae when they hatch extend their galleries directly across the grain of the sapwood, thereby completing the girdling of the tree. The effect of the gridling process therefore does not become evident in the foliage until the broods are well advanced. For this reason the fading phase is delayed and a much larger percentage of the overwintering trees remain green and fade during the spring than is the case of trees attacked by the western pine beetle.

With this exception the advance of the color phases does not differ greatly from that of trees attacked by the western pine beetle in yellow pine. The pronounced variations of the fading and sorrel color phases are not so evident as in the case of the western pine beetle. Trees which fade in the spring and early summer reach the red stage before the first winter and remain red through the following winter, spring and summer. The black condition is reached during the second winter after attack. Thus, as in the brevicomis trees, the fading sorrel and red phases cover a period of about two years. Exceptions, however, are more or less frequent.

Evidence of Attack at the Base.

Pitch-tubes on resistant trees are one of the most reliable evidences of attacks by this species. The number and size of pitch tubes seem to depend to a very great extent upon the vitality of the trees. Weakened and decadent trees

and even healthy trees sometimes fail to produce noticeable pitch tubes. Where the attack is upon strong thrifty trees pitch-tubes become conspicuous within a week or so after attack. This is especially true of attacks in yellow pine and lodgepole pine.

Sawdust borings produced by this species are conspicuous enough to be useful in locating attacks. Some of these borings lodge in the crevices and there is also an accumulation of them near the base of the tree.

Woodpeckers work upon the broods in advanced stages and their work usually consists of irregular holes in the bark over the pupal cells of the beetles. This work is quite distinct in appearance from that which results from bird work on western pine beetle infestations.

Seasonal Conditions Affecting
Field Work.
Cruising Periods

Of fundamental importance in the intrepretation of data is an understanding of the seasonal conditions of the period during which the field examination is made.

Normally there are four cruising periods corresponding to the four annual seasons. The faded trees which can be seen and counted during one season may represnent a different period of loss from those which may be counted during another season of the same year. A knowledge of the character of the data which may be secured during one season is essential to an intellignet reconnaissance of a locality.

Some periods may possess very evident advantages over others for conducting field work. To a great extent these advantages vary locally depending upon weather conditions. In some regions winter reconnaissance is practical, while in others any attempt to carry on extensive surveys during this period involves great loss of time and effort. Periods of rain, snow, fog and dark cloudy weather cannot be utilized for extensive veiwing. The estimator must depend upon periods of bright clear weather when the visibility is good for all extensive surveys. Certain periods during the spring, summer and fall offer the more favorable conditions. Late

spring and early summer usually offer the best conditions of the entire year for this work as a large percent of the infested trees have faded and there are frequent periods of excellent visibility. During the late summer and fall, especially if the season has been rainless, an atmospheric haze obscures the distance making any sort of veiwing difficult and unreliable. If forest fires are prevalent it is impossible to conduct satisfactory work until the atmosphere is cleared by rain or other weather changes.

During the late fall after the first early storms there are usually periods of clear weather which offer another very favorable time for extensive surveys. Occasional clear weather during the winter makes it possible to carry on some work during this season, but seldom does this condition presist long enough to permit the completion of a survey of a large area.

Period of Loss Represented by Color Phases.

When an examination is made at any season of the year the color phases of the insect-killed trees can be classed as fading, sorrel, red or black, representing on the whole either infested or abandoned trees which have been attacked within the two preceeding years. The color phase represents on the whole

phase indicates with considerable certainty whether the tree is infested or abandoned and approximately the date when it was attacked. With certain evident exceptions the period of loss represented by the various color phases during each season can be determined according to the following tables:

-SPRING PERIOD.-

March - April - May .

Color of Foliage	Condition of Infestation	Period of Attack.
Fading and sorrel:	Infested. (Overwintering broods)	Preceding fall.
Bright Red	Infested by advanced stages or partially abandoned. (Summer broods.)	Preceding summer.
Dull red needles drooping but most of them still on	Abandoned (Summer broods.)	Preceding spring and summer.
Dull red- turning black at top. Many needles gone	Abandoned.	Summer and fall of second preceding year.
Black.	Abandoned	Includes a few trees killed in fall of 2nd preceding year, and all trees dead 2 to 8 years.

-SUMMER PERIOD.-

June - July - August .

Fading and sorrel:	Infested (Summer broods.)	Current season.
Bright red	Abandoned (Overwintering broods.)	Preceding fall.
Dull red needles drooping and falling.	Abandoned. (Summer broods.)	Preceding spring and summer.
Dull red top. Usually black. Many needles gone:	Abandoned.	Fall of second preceding year.
Black	Abandoned.	Includes a number of trees killed in fall of 2nd preceding year and all trees dead 2 to 8 years.

FALL PERIOD

September- October- November

Color of Foliage:	Condition	Period of Attack
Fading and sorrel	infested (summer and overwintering broods)	current season, spring, summer and fall
Bright red	infested, partially abandoned or abandoned (summer brood trees)	current season, spring and summer.
Dull red	abandoned(overwintering brood trees of last season)	Fall of preceeding year
Dull red-tops usually turning black	abandoned:(summer brood trees of past season)	spring and summer of preceeding year
Black	abandoned(a few trees from summer broods of past season, and all years preceeding)	spring of preceeding year and two to six years previous

WINTER PERIOD

December - January - February

Fading and sorrel	infested(overwintering brood trees)	preceeding fall
Bright Red	infested by advanced broods or abandoned (summer and also overwintering brood trees)	Preceeding fall and summer
Dull Red-needles drooping	abandoned(summer brood trees	Preceeding spring and summer
Dull Red-many needles fallen	abandoned (overwintering brood trees)	Fall of second preceeding year
Tops Black-some red needles on lower limbs	abandoned (summer brood trees	Spring and summer of second preceeding year
Black	abandoned (some summer brood trees of second preceeding year and all previous years)	summer of second preceeding year and two to six years previous

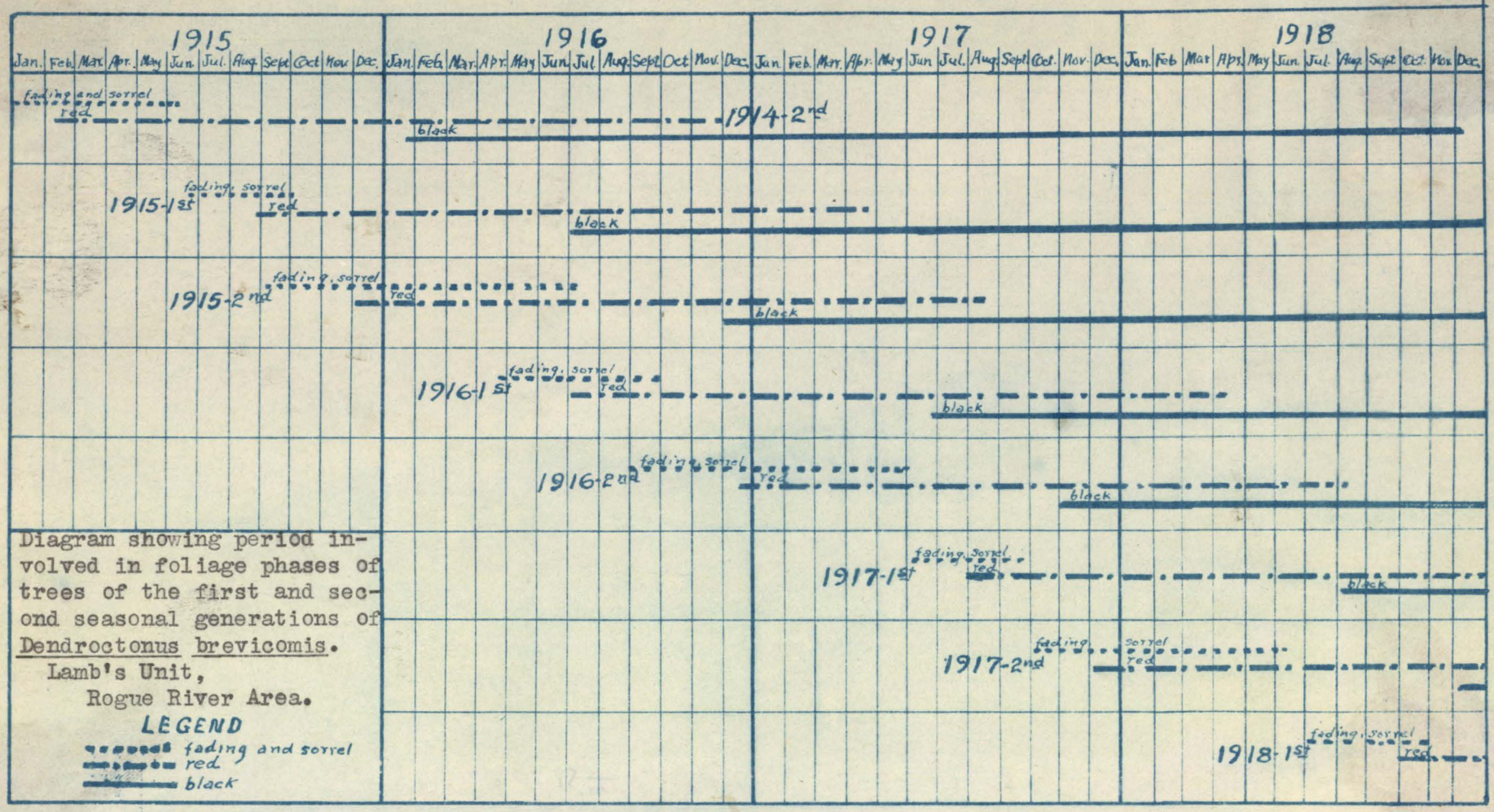

Diagram showing period involved in foliage phases of trees of the first and second seasonal generations of Dendroctonus brevicomis.
Lamb's Unit,
Rogue River Area.

LEGEND
fading and sorrel
red
black

Examples of Application

Extensive Veiwing.

Assuming that an examination of a tract of timber of 10,000acres is made in May 1918 the following count of fading, sorrel and red trees is arrived at by topographic veiwing:

	Yellow Pine	Sugar Pine
Fading and sorrel	60	10
Bright red	50	5
Dull red	35	8
Dull red, turning black	40	10
Total	185	33

In an examination made at this date very few if any of th trees which have been attacked during the spring of 1918 have changed to fading foliage. Trees belonging to the seasonal loss of this year can therefore be thrown out of consideration. The fading and sorrel trees which have been counted represent overwintering brood trees attacked in the late summer and fall of 1917. These trees will be found infested.

Trees with bright red foliage also represent the 1917 trees overwintering broods and may also be infested but with well advanced broods. In some of themthe new adults have already started to emerge and the bark is partially abandoned.

Trees with dull red folaige and drooping needles will be entirely abandoned. These represent the 1917 summer broods and were attacked during the late spring and early summer of that year.

Trees in the final stage of dull red, many of the needles having fallen so that the foliage is approaching the black stage are trees which have passed through the second winter after attack. Many of these trees are from the 1916 oversintering brood trees and

were attacked during the late summer and fall of that year. Some trees of the 1916 loss however will have reached the black top stage and cannot be distinguished in extensive veiwing. For this reason all a part of the 1916 loss is not included in the estimate. The period involved in the attack upon the trees represented by the above count can therefore be apportioned as follows:

	Yellow Pine	Sugar Pine
1917 Loss: fading, sorrel, bright red, and dull red, all of foliage retained:	145	23
1916 Loss: dull red to black: foliage falling and nearly gone:	40	10
total	185	33

Thus the period of loss represented by this count i covers approximately the two seasons of 1917 and 1916, but a small but variable percent of the 1916 loss is not distinguishable.

As a further example we will assume that an examination of the same tract is made in August, 1918, with the following result:

	Yellow Pine	Sugar Pine
Fading and sorrel	30	7
Bright red	100	8
Dull red	45	8
Dull red turning black	38	11
Total	203	37

At this time the foliage of many trees which have been attacked during the the spring and summer of 1918 have turned from green to fading or sorrel. The trees which are counted in this folaige condition are, as a rule, infested and can be included in the 1918 loss. The overwintering brood trees of 1917 have all advance to the first or second

39. In other words in the extensive survey he was able to see about 41% of the trees that actually existed on the plot. This indicates that the factors such as topography, density of stand, or low visibility limited the number of trees which he could see on the entire area to the same extent as on thetsample plot, an in order to arrive at an estimate of the total loss he must modify the results of his extensive count accordingly To the number of trees which were counted in August a factor of 2.4 is applied and the total annual loss for the two seasons represented is estimated as follows:

	No.trees counted	factor	Total no.trees	Av.Volume	Total volume
Yellow Pine	168	2.4	403	970	390,010
Sugar pine	24	2.4	58	4000	232,000
Total	192		461		622,010

We have then a total of 622,010 board feet of timber which has been killed upon the area under survey duringthe seasons of 1916, 1917 and 1918 . Only a portion of the 1916 and 1918 losses are represented however and on the whole we have here an estimate of the equivalent of about two complete seasons of annual loss.

From the sample plot data it will be seen that in yellow pine D.brevicomis is responsible for 94% of the loss and D.monticolae for 1.5%. The topkilled trees which do not represent actual loss, but which indicate a certain type of infestation existing on the area, approximate 4.5% of the volume of the timber which has been counted.

In sugar pine D.monticolae was the only species found at the base of the trees which were examined. It is also assumed that D.monticolae is responsible for the topkilled sugar pine which represent 25% of the affected volume.

dtsges of red. The summer brood trees of 1917 have advanced but little , while more of the 1916 summer and overwintering brood trees have reached the black stage. Thus we have trees representing three consecutive seasons, i.e. part of 1916, all of 1917 and part of 1918.

In the sugar pine, however, very few trees attacked in the summer of 1918 have faded. Some of the trees attacked in 1917 and overwintering as green have faded since May and are now in the sorrel or bright red stage. Aside from this the status of the sugar pine loss does not differ in any degree from that in yellow pine.

	Yellow Pine	Sugar Pine
1918 Loss: fading and sorrel	30	7
1917 Loss: bright red, dull red	100	16
1916 Loss: dull red to black	38	9
Total	168	24

It is evident that the examination in May invloved only trees killed during the two preceeding years; while the examination in August included trees killed during the current season of 1918 as well as those killed in 1917 and 1916. However some of the trees of the 1916 loss which could be seen in May cannot be distinguished in August due to the advance of the foliage to the black stage. Possibly only 50% of the 1916 loss is distinguishable. Also only a limited percent of the trees which will constitute the 1918 loss have changed to the faded foliage condition by August. On the whole the trees of all color phases which can be seen in August represent in actual time about two years of annual loss.

While this data furnishes an indication of the infested condition of the forest it is incomplete and unsatisfactory for a number of reasons. First of all, these figures represent only the actual number of trees which can be seen from a considerable distance. There are without doubt more trees upon the area which cannot be seen in the extensive

veiwing. The data is also incomplete because the diameters and volumes of the affected trees are not known and the cause of their death has not been definitely determined except for such individuals as could be conveniently examined during the progress of the extensive veiwing.

Sample Plots

As a basis for a more reliable estimate of the insect-killed timber, the estimator may select an area of from 600 to 1200 acres as a sample plot. This may consist of a legal subdivision, such as a section, or a topographic unit bounded by streams, ridges or type, which has been carefully selected as a representative part of the entire area under consideration.

Assuming that In the extensive reconnaissance the estimator counted within the limits of the sample plot, 12 yellow pine and 4 sugar pine, he uses this data as a basis for comparison with the number of trees which he will be able to find in an intensive cruise of the same plot. He now works the sample plot closely and makes a basal examination and measurement of every infested and abandoned trees. By this method he is able to arrive at the volume of insect-killed timber, the primary infesting insects and probable period of attack for each trees

	Yellow Pine			Sugar pine		
	No.trees.	Av.volume.	Total volume:	No.trees.	Av.Volume:	Total Vol.
Extensive count, fading sorrel and red - -	12	?	? :	4	?	?
Actual cruise, fading sorrel and red						
D.brevicomis- - - -	24	1000	24,000 :	-	-	-
D.monticolae- - - -	1	400	400 :	9	4000	36,000
Topkilled - - - -	2	900	1,800 :	3	4000	12,000
Total	27		26,200	12		48,000

It will be seen that in the extensive viewing the estimator counted but 16 trees while in a close survey of the area he found

Upon this basis it is possible to apportion the loss according to the primary infesting species of insects as follows:

Yellow Pine

Primary species	% of volume	volume
Dendroctonus brevicomis	94%	366,610
" monticolae	1.5	5,850
Topkilled	4.5	17,550
Total	100.	390,010
Sugar Pine		
Dendroctonus monticolae	75%	174,000
Topkilled	25.	58,000
Total	100.	232,000

It may still be desireable to apportion the loss according to year of attack for each primary species of infesting insect. This may be done by applying the percentages represented in the above table to the apportioned loss according to number of trees and average volumes as worked out from the extensive counts. However the sample plot data is the basis for determining the relative loss due to each primary species of insects and it is usually much more satisfactory to rely upon this entirely for a systematic estimate of the amount of timber killed annually by each species.

From an analysis of the foliage and bark conditions of the trees marked on the sample plots the losswas apportioned upon the following basis:

	YELLOW PINE						SUGAR PINE		
	D.brevicomis		D.monticolae		Top-killed		D.monticolae		Topkilled
	No.trs.	Volume	No.trs.	Volume	No.trs.	Volume	No.trs.	volume	No.trs. Vol.
1916	4	5000-20.9%	-		-		4	16,000 44.4	
1917	17	16000-66.6%	1	400-100%	3	1200 66.6	5	16,000 44.2	8,000 66.6
1918	5	3000-12.5%	-	-	1	600 33.4	1	4,000 11.2	1 4,000 33.4
	24	24,000-100%	1	400 100%	4	1800 100%	9	36,000 100.3	12,000 100%

Assuming that these percentages apply to the loss for the entire area, we can apportion the the annual loss for each primary species as follows:

Yellow Pine

	D.brevicomis		D.monticolae		Topkilled	
	%	volume killed:	%	volume killed:	%	volume
1916	20.9	76,578	-	-	-	-
1917	66.6	244,406	100.	5,850	66.6	11,706
1918	12.5	45,626	-	-	33.4	5,844
	100.	366,610	100.	5.850	100.	17,550

Sugar Pine

	D.monticolae		Topkilled	
	%	volume killed	%	volume
1916	44.4	103,008	-	-
1917	44.4	103,008	66.6	38,667
1918	11.2	25,984	33.4	19,333
	100.	232,000	100.	58,000

The estimates so arrived at can be considered only an approximation of actual conditions owing to the many factors of error which are inevitable in work of this character.

No. 1. Yellow pine tree on the Lamb's Mine Unit which was attacked by the 2nd generation of D. brevicomis in the fall of 1918. At the time the photograph was made, Feb 15, 1919, the entire foliage was bright red. Negative on Wratten and Wainwright Panchromatic plate under Series A conrtast filter.

No. 3. A top killed tree on the Frederick Unit. March 20, 1919 the foliage on the upper branches and top was bright red; that below was normal green to fading.

No. 2. Heavy stand of pine on the Lamb's Mine Unit showing 2 infested yellow pine trees which were attacked by D. brevicomis in fall of 1918. The picture was made Feb 15, 1919, at this time the foliage of both trees was bright red.

No. 6. Frederick Unit. The large yellow pine tree in the foreground is infested with D. brevicomis. The foliage is sorrel below; red above. Note the faded yellow pine tree in the background. All other trees shown are normal green. March 20th 1919.

No. 5. A portion of the yellow pine stand on the Federick Unit showing faded trees infested with D. brvicomis. Note the lighter tone of these trees as compared with the surrounding healthy forest. March 20, 1919.

No. 4. A portion of the Frederick Unit showing a number of faded yellow pine trees infested with D. brevicomis. March 20, 1919.